What is claimed is:

1. A plasma immersion ion implantation reactor for implanting a species into a workpiece, comprising:

an enclosure comprising a side wall and a ceiling defining a chamber;

a workpiece support pedestal within the chamber for supporting a workpiece having a surface layer into which said species are to be ion implanted, said workpiece support pedestal facing an interior surface of said ceiling so as to define therebetween a process region extending generally across the diameter of said wafer support pedestal;

a source power applicator;

an RF plasma source power generator coupled to said source power applicator for inductively coupling RF source power into said chamber;

gas distribution apparatus for furnishing process gas into said chamber;

a supply of process gas for furnishing to said gas distribution devices a process gas containing said species; and

an RF bias generator connected to said workpiece support pedestal and having an RF bias frequency for establishing an RF bias.

2. The apparatus of Claim 1 wherein said RF bias generator has a bias RF frequency that is sufficiently low for ions in a plasma sheath near said workpiece to follow electric field oscillations across said sheath at said bias frequency.

3. The apparatus of Claim 2 wherein said bias RF frequency is sufficiently high so that RF voltage drops across dielectric layers on said workpiece do not exceed a predetermined fraction of the RF bias voltage applied to said workpiece support.

4. The apparatus of Claim 3 wherein said predetermined fraction corresponds to about 10%.

5. The apparatus of Claim 1 wherein said RF bias generator has a bias frequency between 10 kHz and 10 MHz.

6. The apparatus of Claim 1 wherein said RF bias generator has a bias frequency between 50 kHz and 5 MHz.

7. The apparatus of Claim 1 wherein said bias generator has a bias frequency between 100 kHz and 3 MHz.

8. The apparatus of Claim 1 wherein said bias power generator has a bias frequency of about 2 MHz to within about 5%.

9. The reactor of Claim 1 wherein said enclosure further comprises a base, and said gas distribution apparatus comprise plural devices near interior surfaces of said reactor comprising one of: (a) said ceiling, (b) said side wall, (c) said base.

10. The reactor of Claim 1 wherein said plasma bias is a bias voltage corresponding to an implantation depth to which said species is to be implanted in said surface layer.

11. The reactor of Claim 1 wherein the workpiece support pedestal comprises an electrostatic chuck, said electrostatic chuck comprising thermal control apparatus for workpiece temperature control.

12. The reactor of Claim 1 further comprising a gas supply containing said process gas.

13. The reactor of Claim 12 wherein said species to be

implanted comprises a first atomic element, said process gas further comprising:

a second atomic element in chemical combination with said first atomic element.

14. The reactor of Claim 13 wherein said surface layer of said workpiece is a semiconductor material and said first atomic element is an n-type or p-type conductivity dopant impurity with respect to said semiconductor material.

15. The reactor of Claim 14 wherein said second atomic element comprises a semiconductor element.

16. The reactor of Claim 15 wherein said second atomic element and said semiconductor material of said surface layer are the same atomic element.

17. The reactor of Claim 14 wherein said second atomic element is an element having a greater tendency than said first atomic element following ion implantation to diffuse out of said surface layer upon heating of said surface layer.

18. The reactor of Claim 14 wherein said second atomic element comprises one of hydrogen and fluorine.

19. The reactor of Claim 14 wherein the chemical combination of said first and second atomic species comprises a first molecular species, said process gas further comprising a second molecular species.

20. The reactor of Claim 19 wherein said second molecular species comprises one of: (a) hydrogen-containing gas, (b) fluorine-containing gas.

21. The reactor of Claim 19 wherein said second

molecular species comprises a diluent gas.

22. The reactor of Claim 21 wherein said first molecular species comprises a fluoride of said dopant impurity and said second molecular species comprises a hydride of said dopant impurity.

23. The reactor of Claim 22 wherein said process gas further comprises a third molecular species.

24. The reactor of Claim 23 wherein said third molecular species comprises a diluent gas.

25. The reactor of Claim 23 wherein said third molecular species comprises at least one of (a) hydrogen-containing gas, (b) fluorine-containing gas, (c) an inert gas.

26. The reactor of Claim 1 wherein said gas distribution apparatus comprises a gas distribution plate on said ceiling.

27. The reactor of Claim 1 wherein said gas distribution apparatus comprises a gas distribution ring on said wall.

28. The reactor of Claim 1 wherein said enclosure further comprises a base, and said gas distribution apparatus comprises a plurality of discrete gas injection nozzles or diffusers on one of: (a) said side wall, (b) said ceiling.

29. The reactor of Claim 1 wherein said RF bias generator comprises an RF bias power generator coupled to said workpiece support pedestal to control a sheath voltage across a plasma sheath overlying said workpiece support

pedestal.

30. The reactor of Claim 1 wherein said RF bias generator comprises an RF bias voltage generator coupled to said workpiece support pedestal to control a sheath voltage across a plasma sheath overlying said workpiece support pedestal.

31. The reactor of Claim 30 wherein said bias power generator has an RF bias frequency sufficiently low to enable ions traversing the plasma sheath to attain an energy corresponding to a peak-to-peak voltage of said RF bias voltage generator.

32. The reactor of Claim 29 wherein said RF frequency is sufficiently high to limit RF voltage drops across dielectric layers on said workpiece support pedestal to less than a predeterminded fraction of plasma sheath voltage near said workpiece support.

33. The reactor of Claim 32 wherein said predetermined fraction corresponds to about 10%.

34. The reactor of Claim 1 wherein said gas distribution apparatus is in said ceiling and comprises a center orifice and plural outer orifices in a circle centered on said center orifice, said reactor further comprising:

a gas panel containing a separate gas supplies for respective process gases for doping and for passivating and for removing; and

a gas distribution controller comprising a first set of valves coupling at least one of said separate gas supplies to said center orifice and a second set of valves coupling at least some of said separate gas supplies to said plural outer orifices.

35. The reactor of Claim 1 wherein said gas distribution apparatus comprises first and second sets of plural orifices, said reactor further comprising:

a gas panel containing a separate gas supplies for respective process gases for doping and for passivating and for removing; and

a gas distribution controller comprising a first set of valves coupling at least one of said separate gas supplies to said first set of plural orifices and a second set of valves coupling at least some of said separate gas supplies to said second set of plural orifices.

36. The reactor of Claim 34 wherein:

said gases for doping comprise a fluoride of a dopant species and a hydride of a dopant species,

said gases for passivating comprise a hydride of a passivating species and a fluoride of a passivating species,

said gases for removing comprise an etchant-containing gas and an inert gas; and

said gases for oxidizing comprise oxygen.

37. The reactor of Claim 35 wherein:

said gases for doping comprise a fluoride of a dopant species and a hydride of a dopant species,

said gases for passivating comprise a hydride of a passivating species and a fluoride of a passivating species,

said gases for removing comprise an etchant-containing gas and an inert gas; and

said gases for oxidizing comprise oxygen.

38. The reactor of Claim 36 wherein said gas distribution controller furnishes oxygen exclusively to said center orifice.

39. The reactor of Claim 37 wherein said gas

distribution controller furnishes oxygen exclusively to said second set of plural orifices.

40. The reactor of Claim 1 further comprising a controller for controlling said bias generator to produce a desired bias voltage at said workpiece support pedestal for a predetermined single burst duration.

41. The reactor of Claim 40 wherein said controller comprises:

a timer for switching the output of said bias power generator on and off in accordance with said predetermined duration;

a peak voltage detector coupled to said workpiece support pedestal;

a threshold comparator connected to said timer for comparing the output of said peak voltage detector with a predetermined threshold voltage;

a subtractor having a pair of inputs connected to the output of said peak voltage detector and to a predetermined target voltage, respectively, and a feedback conditioner for processing the output of said subtractor;

a first switch for coupling an output of said feedback conditioner to a power level control input of said bias power generator;

42. The reactor of Claim 41 wherein said controller further comprises a control element for controlling said bias power generator (a) empirically in absence of a plasma in said chamber and (b) in a feedback control loop in the presence of plasma in said chamber.

43. The reactor of Claim 42 wherein said control element comprises:

a voltage-to-power look-up table having an input connected to said predetermined target voltage and an

output;

a second switch coupled between the output of said voltage-to-power look-up table and said power level control input of said bias power generator; and

a plasma detector in said chamber connected to control said first and second switches in complementary fashion in response to detection of plasma in said chamber.

44. The reactor of Claim 43 wherein said plasma detector is further connected to enable said timer.

45. The reactor of Claim 41 wherein said feedback conditioner is an integral proportional controller.

46. The reactor of Claim 41 wherein said predetermined threshold voltage and said predetermined target voltage are identical.

47. The reactor of Claim 41 further comprising a process controller for furnishing said predeterminded target voltage and said predetermined threshold voltage.

48. The reactor of Claim 1 further comprising a vacuum pump and a vacuum control valve coupling said vacuum pump to said chamber, said vacuum control valve comprising:

a valve housing having a valve opening defined by an opening side wall having a surface parallel to an axis of said valve opening;

a rotatable flap subject to process control and having an area conformal with said valve opening and side wall and rotatably mounted within said valve opening to define a gap therebetween; and

a plurality of small indentational voids in said side wall that are covered by said rotatable flap whenever said flap is in a co-planar relationship with said housing and are gradually exposed as said flap rotates away from

said rotational position and before a bottom corner edge of said flap passes a top surface of said valve housing.

49. The reactor of Claim 1 wherein said workpiece support pedestal comprises:

a conductive wafer support plate;

a grounded conductive base plate forming at least a void between said support and base plates;

a side wall around said support and base plates forming at least a void between said side wall and said support and base plates;

a high dielectric filler material having a high break-down voltage filling said voids; and

a conductive insert coupled to said bias power generator and a conductive female receptacle for tightly receiving said conductive insert, said conductive female receptable being connected to said conductive wafer support plate, said conductive insert and said conductive female receptable extending through said conductive base plate to said conductive wafer support plate, and insulating layer insulating said conductive insert from said conductive base plate.

50. The reactor of Claim 49 wherein said workpiece support pedestal further comprises at least one lift pin assembly extending through said conductive base plate and said conductive wafer support plate and a axial void between said lift pin assembly and said lift pin assembly, and a high dielectric filler material having a high breakdown voltage within the void between said lift pin assembly and said conductive wafer support plate.

51. The reactor of Claim 50 further comprising a fastening bolt extending at least partially through said conductive wafer support plate and to said conductive base plate, and a high dielectric filler material having a high

breakdown voltage surrounding a portion of said bolt within said conductive wafer support plate.

52. The apparatus of Claim 1 wherein said RF source power generator and said RF bias generator comprise first and second pulsed RF supplies, respectively.

53. The apparatus of Claim 52 wherein said first and second pulsed RF supplies are in a push-pull relationship.

54. The apparatus of Claim 52 wherein said first and second pulsed RF supplies are in an in-synchronism relationship.

55. The apparatus of Claim 52 wherein said first and second RF supplies are in a symmetric relationship.

56. The apparatus of Claim 52 wherein said first and second RF supplies are in a non-symmetric relationship.

57. The apparatus of claim 1 wherein the source power applicator is an inductive coil.

58. The apparatus of claim 1 wherein the source power applicator is an antenna.